

LA-UR -81-3119

TITLE: LCT PROTECTIVE DUMP-SWITCH TESTS

AUTHOR(S): W. M. Parsons

MASTER

SUBMITTED TO: Proceedings of the 9th Symposium on Engineering Problems
of Fusion Research, Chicago, IL, October 26-29, 1981

University of California

By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes.

The Los Alamos Scientific Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.



LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer

LCT PROTECTIVE DUMP SWITCH TESTS*

W. M. Parsons
Los Alamos National Laboratory
Los Alamos, NM 87545

Summary

Each of the six coils in the Large Coil Task (LCT) has a separate power supply, dump resistor, and switching circuit. Each switching circuit contains five switches, two of which are redundant. The three remaining switches perform separate duties in an emergency dump situation. These three switches were tested to determine their ability to meet the LCT conditions.

The power supply crowbar switch in LCT is required to close on 25 kA at a low voltage and to carry this current on a continuous basis. An oil cooled, high current bypass switch was successfully tested for over 200 make operations at 25 kA and run continuously for eight hours without excessive temperature rise.

The interrupter bypass switch in LCT is required to carry 22.5 kA continuously and to interrupt this current and divert it into a parallel connected dc interrupter. It must then withstand a 5 kV arc voltage generated by the dc interrupter followed by a 2.5 kV dump resistor voltage. More than 200 synthetic tests were performed at 25 kA and 10 kV. Almost 40 additional tests involving full current transfers and circuit breaker interruptions were also completed. Both sets of tests were done with and without oil in the switch.

The dc interrupter in LCT is required to divert 25 kA into a 0.1 ohm, 20 μ H resistor. This commercially available switch was subjected to over 120 interruptions ranging from 5 to 24 kA. Although every interruption was successful, the breaker had considerable trouble interrupting currents with recovery voltages in excess of about 1.5 kV. Two interrupters connected in series improved performance at these higher voltages.

Introduction

LCT at the Oak Ridge National Laboratory (ORNL) will test an array of six superconducting tokamak toroidal field coils. The high energy and cost associated with each coil necessitates the use of a protective dump circuit in an emergency situation.¹ Five individual switches and a dump resistor comprise each protective dump circuit. Two of the five switches are redundant.

The three remaining switches are the power supply crowbar switch (PSCS), the interrupter bypass switch (BP), and the dc circuit breaker (DCCB). Both PSCS and BP are modified versions of a switch that was originally developed at Los Alamos for use in a high current vacuum interrupter system. The redundant switches include another interrupter bypass switch and dc circuit breaker which are used as a secondary system if the primary system fails.

Figure 1 is a schematic of the protective dump circuit for a single coil. The system operates as follows. All switches are initially closed except PSCS, and 90% of the current flows through BP₁ and BP₂ while 10% flows through DCCB₁ and DCCB₂. When a signal is received to initiate an emergency dump, a signal is

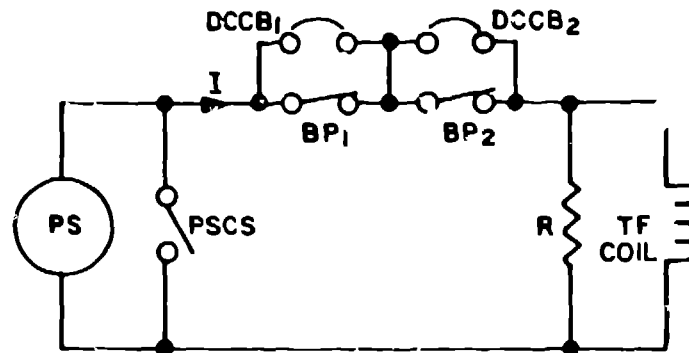


Fig. 1. Protective dump circuit.

given to PSCS to close and to the power supply to turn off. The closure of PSCS removes the output inductance of the power supply thus easing the interruption duty of DCCB and also protects the power supply from any voltage transients. When PSCS has closed, BP₁ begins to open. This transfers the full current into DCCB₁. When BP₁ has fully opened, DCCB₁ is given a signal to trip. The opening of DCCB₁ creates a high arc voltage and transfers all the current to dump resistor R. If for some reason this transfer is not completed, redundant switches BP₂ and DCCB₂ then open in the same sequence as BP₁ and DCCB₁.

The six coils in LCT operate at different maximum current ranging from 14 to 24 kA. The dump resistor will be 0.1 ohms resulting in maximum recovery voltages ranging from 1.4 to 2.5 kV. Tests were conducted at currents ranging from 5 to 25 kA on all switches and are detailed in the following sections.

Power Supply Crowbar Switch

The power supply crowbar switch has two basic duties--to close on or "make" currents as high as 25 kA and to carry this current on a continuous basis. Figure 2 shows the circuit used to test this switch.

A current of 11 kA is initiated through R while PSCS is open. The switch is then closed causing a diversion of 25 kA through PSCS. Over 200 of these make tests were performed on this switch. There was no

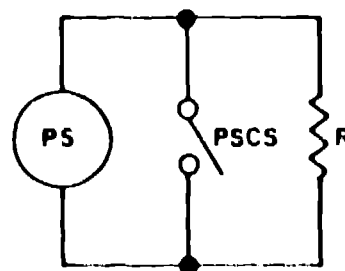


Fig. 2. Test circuit for power supply crowbar switch.

*Work performed under the auspices of the U.S. Department of Energy.

sign of contact bounce or excessive erosion. The switch was then run for eight hours at 25 kA. The temperature rise was no greater than when the contacts were new.

The Interrupter Bypass Switch

The interrupter bypass switch also has two basic duties--to carry 22.5 kA continuously and to "break" this current and divert it into the parallel dc circuit breaker. A picture of this switch in the test facility is shown in Fig. 3. The switch in the background is the PSCS. After transferring the load current to the interrupter, auxiliary contacts on BP energize the trip coil of the dc circuit breaker. This circuit breaker generates arc voltages as high as 5 kV. BP must not restrike under these voltage transients.

After temperature rise tests at 22.5 kA were completed, two sets of transfer tests were performed on this switch. The first set was a synthetic test which utilized the circuit of Fig. 4.

Initially, all switches except S are closed and PS is set to 25 kA. BP is then opened to transfer the full current to DCCB which then opens. Because of the limited energy stored in the inductance of the power



Fig. 3. Interrupter bypass switch (foreground) and power supply crowbar switch (background).

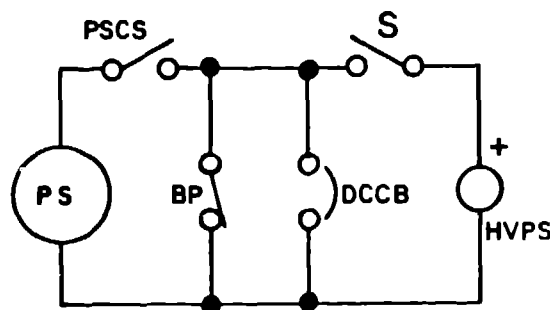


Fig. 4. Synthetic test circuit for BP.

supply loop, the arc in the DCCB clears without moving into the 5 kV arc chute. PSCS now opens on zero current and S is closed. The high voltage power supply, HVPS, is set to 10 kV; and this voltage appears across BP, simulating twice the arc voltage that would have been generated by DCCB had sufficient energy been stored in the loop. Over 200 tests were performed in this manner with no breakdown of BP. The oil was then drained from BP, and the test was repeated with no oil in the contact gap. The switch still performed satisfactorily. When the contact stroke was reduced to one half the normal stroke, a breakdown was observed. This exercise was done to determine if the switches had sufficient dielectric strength to run in the absence of a circulating oil bath. The switch was then tested again for continuous current temperature rise.

The second set of tests were full power transfers with subsequent high arc voltage interruptions. These were also done with and without oil in BP. All of the 40 interruptions in this set were successful.

The DC Circuit Breaker

The dc circuit breaker selected by ORNL for use in LCT is a Westinghouse type DMD semi-high speed, air magnetic circuit breaker. This interrupter has a 4 kA continuous current rating and a special 5 kV arc chute. The nominal voltage rating is 1.5 kV. Figure 5 is a photograph of two of these interrupters connected in series in the test facility.

Tests began on a single circuit breaker with the circuit of Fig. 6. In this circuit DCCB and BP are initially closed, S is open, and C is precharged. S now closes and C discharges through L. D₁ crowbars C when L has reached peak current and traps the inductive current in the circuit breaker leg. Now, BP opens to transfer the full current into DCCB which then opens. The arc voltage of DCCB forces the current into R which simulates a protective dump operation.

Almost 100 interruptions, not all of which involved BP, were performed on a single dc circuit breaker. The value of R was varied from 60 to 170 mΩ. The current was varied between 5 and 24 kA while L was either 3.7 or 4.5 mH. All interruptions were successful. When the recovery voltage was under about 1.5 kV, interruptions were generally quite clean and very quick. Figure 7 shows the current through DCCB for a 10 kA, 1.3 kV interruption. When R was changed to higher values and produced recovery voltages greater than 1.5 kV, interruptions were not as clean or quick. Figure 8 shows an 18 kA interruption at 2.25 kV.

During these types of interruptions, the circuit breaker restrikes on the lower contacts while the primary arc is in the arc chute. This restrike then



Fig. 5. Two series connected Westinghouse dc circuit breakers.

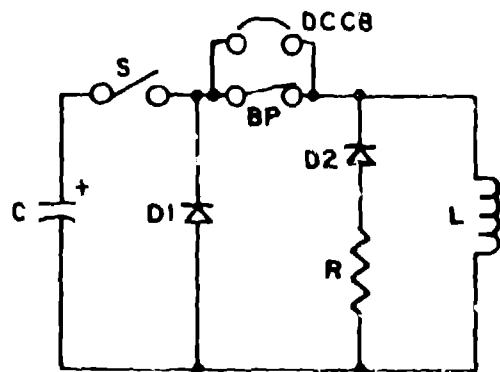


Fig. 6. Circuit breaker test schematic.

becomes the primary arc and moves up into the arc chute and the process repeats. Eventually the breaker clears, possibly due to the uprush of heated gas generated by the prolonged arcing process.

Two breakers were connected in series in an attempt to obtain clean interruptions at higher voltages. This attempt was only partially successful

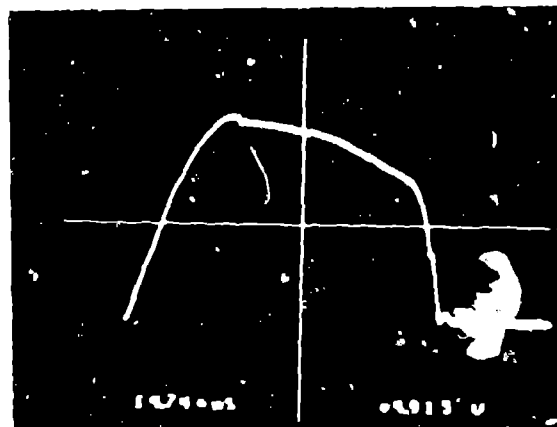


Fig. 7. 19 kA, 1.3 kV interruption.

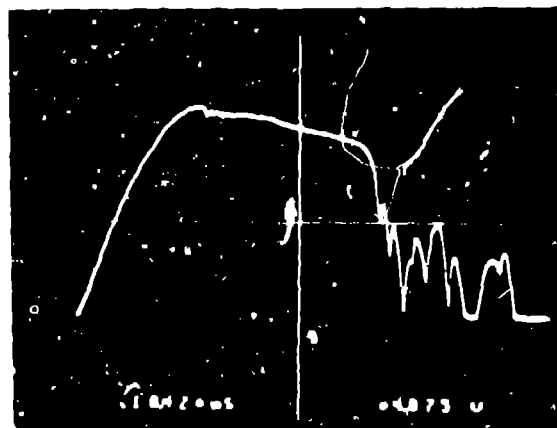


Fig. 8. 18 kA, 2.25 kV interruption.

due to the high jitter of these circuit breakers. When both interrupters opened simultaneously, interruption was quite good; however, this was achieved only about 25% of the time. The rest of the time, one of the breakers would open early, and the restriking process would continue until the switch cleared or until the other breaker opened sufficiently to assist. Although interruption was always achieved in these tests, the restriking causes an accelerated erosion of the contacts and contamination of the insulators in the arc chute which would eventually lead to failure of the device.

Conclusions

The power supply crowbar switch and the interrupter bypass switch were both able to carry their continuous design currents of 24 and 22.5 kA and successfully perform their respective making and breaking duties. No adverse erosion was detected in either device after several hundred operations. These devices should be able to operate more than 1000 times before maintenance is required. In addition, the bypass switch was able to withstand reliably twice the expected voltage after current transfer to the DCCB.

The dc circuit breaker had no failures to interrupt in any of the tests performed in which currents ranged from 5 to 28 kA and recovery voltages from 0.8 to 2.6 kV. Interruptions with recovery voltages greater than about 1.5 kV were characterized by multiple restrikes before final clearing. Tests with two circuit breakers in series showed some improvement in clearing time although this was strongly dependent on the simultaneous opening of both breakers. This simultaneous opening was hard to achieve because of the high jitter of the devices.

References

1. W. M. Parsons and R. J. Wood, "Protective Circuits for Superconducting Magnets", Proc. 4th ANS Topical Meeting on Technology of Controlled Nuclear Fusion, King of Prussia, PA, Oct. 14-17, 1980.
2. E. M. Honig and R. W. Warren, "The Use of Vacuum Interrupters and Bypass Switches to Carry Currents for Long Times", Proc. 13th Pulse Power Modulator Symposium, Buffalo, NY, June 20-22, 1978.